

## **AMENDMENT**

### **IN THE SPECIFICATION**

After the title of invention, please add the following section heading and sentence:

### **REFERENCE TO RELATED APPLICATIONS**

This application claims priority to PCT Application PCT/EP03/050360 filed on August 4, 2003, which claims priority to Belgian Patent Application BE 2002/0469 filed on August 6, 2002.

Before the first paragraph on page 1, line 4, please insert the following section header:

### **BACKGROUND OF THE INVENTION**

Please amend the paragraph starting on page 2, line 7 as follows:

Gruber et al. envisage an integrated process for the synthesis of PLA starting from a solution (more or less pure) of lactic acid and/or of one of its esters comprising:

1. in one or two stages, evaporation of the free water and of a portion of the bonded water, so as to produce an oligomer with a molecular mass of between 100 and 5000 amu;
2. mixing the depolymerization catalyst with the oligomer, followed by thermal cracking of the mixture with production of lactide in the ~~vapour~~vapor form;
3. selective condensation of the ~~vapours~~vapors, followed by fractional distillation, making it possible to recover a purified lactide; and
4. polymerization of the purified lactide by ring opening to produce PLA.

Please amend the paragraphs starting on page 2, line 25 and ending on page 3, line 23 as follows:

O'Brien et al. envisage an integrated process for the synthesis of the purified lactide for PLA starting from an aqueous lactic acid solution comprising at least 50% by weight of lactic acid comprising:

1. evaporation of the free water and of a small portion of the bonded water, so as to produce an oligomer comprising a number of monomer units (n) of between 2 and 8;
2. continuing the evaporation characterized by a greater diffusion surface area for the polymer and making it possible to obtain an oligomer comprising a number of monomer units (n) of between 8 and 25, stages 1 and 2 being carried out in equipment having a structure characterized by a low iron content;
3. mixing the depolymerization catalyst, devoid of alkali metals, with the oligomer, followed by thermal cracking of the mixture at a temperature below 240°C with production (a) of a vapour phase comprising lactic acid, water, lactide and entrained heavy oligomers and (b) of a liquid phase comprising the heavy oligomers;
4. extraction of the fraction in the ~~vapour~~vapor form (a), so that its residence time in the cracking region is less than 15 seconds;
5. selective condensation of the ~~vapours~~vapors, followed by fractional distillation, making it possible to recover, by an intermediate extraction, a prepurified lactide in the liquid form; and
6. melt crystallization of the prepurified lactide, so as to result in a purified lactide fraction characterized by a residual acidity of less than 6 meq/kg.

Please amend the paragraph starting on page 4, line 10 as follows:

In point of fact, by the purification technology selected, namely distillation, it is impossible to obtain, first, an optically pure product [the ~~vapour~~vapor pressure curves of the various stereoisomers (L-lactide or L-LD, D-lactide or D-LD, meso-lactide or meso-LD) being much too close, which proves to be essential for applications requiring a degree of crystallinity of the polymer] and, secondly, a chemically pure product as, by their own admission, they recognise that they cannot totally avoid the opening of the lactide ring in the distillation column and thus the contamination of the lactide in the system.

Please amend the section header on page 5, line 5 as follows:

**Brief description of the invention****SUMMARY OF THE INVENTION**

Please amend the paragraph starting on page 5, line 6 and ending on page 6, line 16 as follows:

In the continuation of this text, unless otherwise indicated, the percentages are expressed by weight and the molecular masses by atomic mass unit (amu). In a first embodiment, the invention consists of a low-temperature integrated process for the production and purification of lactide starting from an aqueous solution of lactic acid or of lactic acid derivatives, comprising:

- a) evaporation of the free water and of a portion of the water of constitution until oligomers having a molecular mass of between 400 and 2000 amu, a total acidity as lactic acid equivalent of between 119 and 124.5% and an optical purity, expressed as L-lactic acid, of between 90 and 100% are obtained;
- b) feeding the mixture comprising a depolymerization catalyst and the oligomers obtained in a) to a depolymerization reactor with production of:
  - b1) a lactide-rich ~~vapour~~vapor phase, and
  - b2) an oligomer-rich liquid residue;
- c) selective condensation of the lactide-rich ~~vapour~~vapor (b1) with recovery, in the liquid form, of a crude lactide product freed from the volatile compounds;
- d) melt crystallization of the crude lactide product (c), with production of a purified lactide fraction having a residual acidity of less than 10 meq/kg, a water content of less than 200 ppm and a meso-lactide content of less than 1%;
- e) aqueous treatment of the residual fractions from the melt crystallization, consisting of:
  - e1) extractive and controlled crystallization of these fractions in an aqueous medium, with control of the geometry of the crystals formed and with segregation of the lactide suspension towards the solid phase and of the impurities towards the liquid phase, so as to carry out aqueous extraction of the impurities;
  - e2) separation of the suspension of crystals (e1) from the liquid phase and then draining, which separates a wet cake rich in lactide crystals from a liquid phase depleted in lactide and laden with impurities;
  - e3) drying the wet cake (e2), which provides the prepurified lactide.

Please amend the paragraph starting on page 5, line 6 and ending on page 7, line 23 as follows:

A second embodiment of the invention consists of a low-temperature integrated process for the production and purification of lactide starting from an aqueous solution of lactic acid or of lactic acid derivatives, comprising:

- a) evaporation of the free water and of a portion of the water of constitution until oligomers having a molecular mass of between 400 and 2000 amu, a total acidity as lactic acid equivalent of between 119 and 124.5% and an optical purity, expressed as L-lactic acid, of between 90 and 100% are obtained;
- b) feeding the mixture comprising a depolymerization catalyst and the oligomers obtained in a) to a depolymerization reactor with production of:
  - b1) a lactide-rich ~~vapour~~vapor phase, and
  - b2) an oligomer-rich liquid residue;
- c) selective condensation of the lactide-rich ~~vapour~~vapor (b1) with recovery, in the liquid form, of a crude lactide product freed from the volatile compounds;
- d) aqueous treatment of the crude lactide product resulting from (c) consisting of:
  - d1) extractive and controlled crystallization in an aqueous medium, with control of the geometry of the crystals formed and with segregation of the lactide suspension towards the solid phase and of the impurities towards the liquid phase, so as to carry out aqueous extraction of the impurities;
  - d2) separation of the suspension of crystals (d1) from the liquid phase and then draining, which separates a wet cake rich in lactide crystals from a liquid phase depleted in lactide and laden with impurities;
  - d3) drying the wet cake (d2), which provides a prepurified lactide;
- e) melt crystallization of the prepurified lactide (d3), with production of a purified lactide fraction having a residual acidity of less than 10 meq/kg, a water content of less than 200 ppm and a meso-lactide content of less than 1%.

Please amend the section header on page 14, line 12 as follows:

**Detailed description of the inventionDETAILED DESCRIPTION OF PREFERRED EMBODIMENT**

Please amend the paragraph starting on page 15, line 26 as follows:

The evaporation will be carried out while taking care very particularly to avoid, on the one hand, excessively high entrainment of lactic units in the water ~~vapours~~vapors extracted and, on the other hand, subjecting the lactic acid and its oligomers to a prolonged thermal stress which would promote racemization reactions.

Please amend the paragraph starting on page 17, line 24 and ending on page 18, line 8 as follows:

The second stage consists of a catalytic and thermal depolymerization of the oligomers obtained above, so as to produce a ~~vapour~~vapor phase rich in lactide. The use of a catalyst proves to be essential in order to reduce the thermal cracking temperature and to avoid the chemical and optical deterioration in the lactide synthesized. The catalyst will be solid or liquid and of Lewis acid type, such as, for example, tin octoate, tin lactate, antimony octoate, zinc octoate, and the like. Its content is between 0.1 and 5 g%. Catalysts of Lewis acid type are characterized by relatively high charge density. In point of fact, it has been demonstrated that these densities promote racemization reactions. In this context, it is preferable to reduce as much as possible the contact time between the catalyst and the oligomers; care will thus be taken to mix the catalyst immediately before it is introduced into the reactor.

Please amend the paragraph starting on page 19, line 7 as follows:

At the top, the ~~vapour~~vapor phase rich in lactide is directly extracted and selectively condensed in a condenser maintained at a very specific temperature. This is because the condenser is maintained at a temperature such that, on the one hand, the volatile compounds, such as water, most of the lactic acid and decomposition products resulting from the synthesis (acetaldehyde, and the like), remain in the ~~vapour~~vapor phase (while the lactide and the heavy compounds are condensed) and not too low, on the other hand, to avoid crystallization of the lactide. Depending on the nature and on the purity of the product collected (crude lactide product), this temperature will be between 70 and 125°C.

Please amend the paragraph starting on page 24, line 7 as follows:

A ~~favourite~~favorite approach of the present invention is the continuous polymerization of the purified lactide by virtue of the addition of the tin octoate/triphenylphosphine pair to a twin-screw extruder (reactive extrusion).

Please amend the paragraph starting on page 27, line 30 and ending on page 28, line 15 as follows:

The mixture is fed continuously via the line 2 to a preheater 100 which brings the mixture to the temperature required for the evaporation of the water, that is to say between 50 and 150°C. It is possible to continuously add to the mixture, via the line 121, an esterification catalyst stored in the vessel 120. During the addition of a catalyst, the preheater 100 will preferably be designed so as to be able to heat and homogenize the mixture. In the evaporator 200, which can operate under vacuum, at atmospheric pressure or under slight pressure, the majority of the free water and a portion of the water of constitution are continuously removed in the ~~vapour~~vapor form via the line 202 and condensed 210. Depending on the content of lactic acid in the condensates, the latter are conveyed either to the hydrolysis vessel 2000 via the line 211 or as back-up water to the extractive crystallization vessel 700 via the line 212 or very simply discharged via the line 213.

Please amend the paragraph starting on page 28, line 16 and ending on page 29, line 5 as follows:

The concentrated lactic acid continuously removed via the line 201 and characterized by an average molecular mass of between 100 and 600 is fed continuously to a preheater 250 which brings the concentrated lactic acid to the oligomerization temperature, that is to say between 80 and 180°C. It is possible to add to the mixture, via the line 261, an esterification catalyst stored in the vessel 260. During the addition of a catalyst, the preheater 250 will preferably be designed so as to be able to heat and homogenize the mixture. In the oligomerization reactor 300, which can operate under vacuum, at atmospheric pressure or under slight pressure, a small amount of free water and a predominance of water of constitution are removed in the ~~vapour~~vapor form via the line 302 and condensed 310. The condensates are conveyed to the hydrolysis vessel 2000 via the line 311. This stage will preferably be carried out under vacuum, without, however, reaching a pressure of less than 40 mbar absolute, so as to accelerate the reaction kinetics and to reduce the operating temperature while avoiding the production of an excessively large amount of the cyclic dimer.

Please amend the paragraph starting on page 29, line 24 and ending on page 30, line 4 as follows:

The catalytic depolymerization reactor 500, which is fed via the line 401 with the oligomer/catalyst mixture, is managed so as to promote the backbiting reaction which generates the lactide. In this context, the temperature will be between 180 and 250°C, the pressure between 0.1 and 40 mbar absolute and the residence time of the mixture under the reaction conditions between 0 and 30 min, preferably between 0 and 15 min. The following are removed from the depolymerization reactor 500: on the one hand, a liquid residue (liquid at the operating temperature) rich in oligomers, which is conveyed via the line 502 to the hydrolysis vessel 2000, and, on the other hand, a ~~vapour~~vapor phase rich in lactide via the line 501.

Please amend the paragraph starting on page 30, line 10 as follows:

The ~~vapour~~vapor phase removed at the top of the reactor 500 and rich in lactide 501 is selectively condensed in a condenser 510, so as to maintain the volatile compounds, such as water, lactic acid and decomposition products resulting from the synthesis, and the like, in the ~~vapour~~vapor form 513 and to recover the lactide and the heavier compounds in the liquid form (crude lactide product) 511. On conclusion of this selective condensation, the crude lactide product is characterized by an L-LD content of greater than 85%, indeed even of greater than 90%, a low meso-LD content of less than 7%, indeed of less than 5% and indeed even of less than 3%, and a residual water content of less than 1000 ppm, indeed even of less than 500 ppm. The condensation temperature is carefully adjusted according to the pressure prevailing in the system and so as to avoid solidification of the lactide. It will be between 70 and 125°C. The volatile compounds removed via the line 513 are condensed in their turn 550 and are transferred, via the line 551, to the hydrolysis vessel 2000.

Please amend the paragraph starting on page 33, line 26 and ending on page 34, line 5 as follows:

Another ~~favoured~~favoured approach of the present invention consists in conveying the crude lactide product 511 resulting from the selective condensation via the line 512 to the extractive crystallization unit 700. In this unit, the crude lactide product is mixed with an aqueous phase fed via the line 702 with a water content which can range from 0 to 40%. The temperature of the mixture is subsequently reduced so as to avoid excessively great supersaturation, so as to control the geometry of the crystals formed and to promote phase segregation between the lactide (solid phase) and the impurities (liquid phase).

Please amend the paragraph starting on page 36, line 3 as follows:

For the depolymerization, the oligomer is mixed with 2% of its weight of tin octoate and fed (25-30 kg/h) to a thin film evaporator maintained at 235°C and with a surface area of 2 m<sup>2</sup>. The ~~vapour~~vapor generated (impure lactide, crude product) is condensed and the product obtained weighed in order to determine the productive output of the system but also analysed in order to determine the selectivity thereof.

Please amend the paragraph starting on page 37, line 16 and ending on page 38, line 2 as follows:

A stirred reactor heated using 2 electrical resistors (1.2 kW and 2.3 kW) was fed with 20 litres of lactic acid sold by Galactic under the “heat-stable” label and characterized by a concentration of 90% and a content of L isomer of 97.6%. The temperature of the heating resistors and in the liquid is regulated so as to avoid any difference of greater than 20°C and to prevent the maximum temperature from exceeding 160°C. In order to facilitate the rapid extraction of the volatile compound, the unit is placed gradually under vacuum, the pressure varying between atmospheric pressure and 150 mbar. In order to avoid excessively great entrainment of lactic acid in the distillates, the reactor is surmounted by a column with a height of 0.90 m and a cross section of 0.09 m filled with Raschig rings (10 × 10 mm). A temperature probe placed at the column top makes it possible to monitor the temperature of the ~~vapours~~vapors and, if necessary, to reduce the heating power in order to prevent excessively great entrainment.

Please amend the paragraph starting on page 38, line 8 as follows:

3% by weight of tin octoate are added to the oligomer obtained above and kept stirred at a temperature of 120°C. The mixture is fed at a flow rate of 3 kg/h to a thin layer evaporator of thin film type made of stainless steel 316 with a surface area of 0.2 m<sup>2</sup>, the walls of which are heated by circulation of oil, the temperature of which is maintained at 220-230°C. The ~~vapours~~vapors generated are condensed in a condenser with a surface area of 1 m<sup>2</sup> made of stainless steel 316, the temperature of the liquid “coolant” of which is maintained between 80 and 90°C. The entire unit is run under a pressure of between 5 and 10 mbar absolute. The crude lactide product is collected at the outlet of the condenser at a flow rate of 2.45 kg/h, has a content of L-lactide varying between 85 and 92% and has a content of meso-lactide varying between 3 and 7%.